IAP9 Rec'd PCT/PTO 03 MAR 2006 10/570839

Method for producing electronic components

The invention relates to several methods for producing electronic components with adjacent electrodes tightly interspaced at distances ranging between 10 nanometers and several micrometers on a substrate of any type that may also be a polymer film or glass, except for substrates for standard semiconductor technology such as Si, SiO_2, Si_3N_4, GaAs, Al_2O_3).

The methods based on the invention find application in the extremely low-cost and simple manufacture of electronic components requiring the smallest electrode separation such as, for example, molecular electronics, polymer field-effect transistors or field emitters.

The State of the Art describes various lithographic procedures (DUV or electron-beam lithography) by means of which the shortest possible length of the electrically active channel within the transistor (channel length), and thereby a high operating speed, may be achieved. However, these high-resolution lithographic procedures are very cost-intensive and therefore not suitable for the application realms of low-performance, low-cost electronics.

Also, a method per Friend, published in SCIENCE 299, 1881 (2003), is known in which a vertical configuration of two lateral metallization layers separated by an insulating polymer layer is used in order to provide short channels in polymer transistors. A blade cuts into this sandwich so that closely adjacent electrode connections M_{e1} and M_{e2} are present at the sidewalls. The polymer semi-conductor ('active layer') is deposited over this V-slot, and then made into a transistor.

The disadvantage here, however, that the material is deformed when pressed into the cut slot, and the opposing sidewalls of the channel are positioned very close to each other. The active layer subsequently deposited cannot be evenly distributed because of meniscus formation.

A method to produce contact structures within semi-conductor components is knows from DE 198 19 200 A1 according to which a recess is formed in the substrate using a mask. Two separate electrode structures may be applied to it by deposition of a conducting material and creation of flanks for the recess.

It is therefore the task of the invention to develop one or more methods with which closely adjacent electrodes may be structured on a substrate in a simple, low-cost manner, and thus allow the production of electronic components with the least possible technological expense.

The solution of this task based on the invention is achieved by the properties of Patent Claims 1, 2, 3, and 4.

In principle, structuring of the electrodes is performed by overlapping the edges on the deposited layer, or by means of undercutting the deposited layer. Finishing of the electronic components occurs subsequently either in a conventional manner or by means of a lithographic process from the underside of the transparent substrate and subsequent succession of known procedure steps to produce electronic components.

The invention will be described in more detail using Figures of a field-effect transistor, which show:

Figure 1 structuring of electrodes by means of overlapping the deposited layer;

Figure 2 structuring of electrodes by means of undercutting a deposited layer;

Figure 3 production of a transistor using known methods;

Figure 4 production method for a field-effect transistor using photo-lithography from the underside of the substrate;

Figure 5 production of a field-effect transistor by means of etching into the depth of the substrate.

Figure 1 shows the steps of a vertical production method. A photo lacquer was deposited on a substrate and was so structured that overlapping edges arise on the photo lacquer. Subsequently, a metal vapor, preferably Chromium or Gold, is deposited. The insulator applied in the subsequent procedure step covers the entire surface. Flat edges are formed on the overlapping edges of the photo lacquer because of meniscus formation during the subsequent etching process as an inverse of the overlaps. The substrate with its mounted and insulated electrodes thus produced may be completed to produce a field-effect transistor in subsequent procedure steps such as scattering the organic semiconductor ('active layer'), deposition of another insulator, and gate metallization and exposure of the electrodes.

Figure 2 shows another method to structure closely adjacent electrodes on a substrate. In this method, a metal vapor, preferably Chromium or Gold, is deposited. Photo lacquer is then deposited onto this metal layer, and is structured according to the components to be produced. In the subsequent method step, the metal is etched at all points not covered by the photo lacquer, whereby the metal is over-cut at the edges of the photo lacquer in a controlled manner.

Overhangs thus are formed on each photo lacquer. Subsequently, the structure thus achieved again receives a deposit of metal vapor. The electrodes are separated from each other by means of the undercutting. After the photo lacquer is removed (lift off) with its deposited metal layer, the desired electronic component (field-effect transistor) may be completed using known method steps by scattering an organic semi-conductor ('active layer') and an insulator, or deposition of gate metallization and exposure-etching of the connectors (Figure 3). To the extent the deeper-positioned electrodes are to form, for example, the gates of a transistor, they are purposefully so covered with an insulator that the recess is also closed by means of it.

Figures 2 and 4 show a production method for an electronic component with closely adjacent electrodes on a substrate for the example of production of a field-effect transistor. The structuring of these closely adjacent electrodes results as in the above-mentioned method (Method 2) up to the point of scattering the insulator. A photo lacquer is subsequently deposited onto this insulator, and photolithography is performed from the underside of the substrate. An absolutely necessary pre-condition for this is, however, that the substrate, the active layer, and the insulator must be transparent. After this lithographic process, a subsequent metal-vapor layer is deposited. In the final step, the remaining photo lacquer with its deposited metal layer is removed (e.g., by a lift-off process).

In order to avoid this lift-off process at the sub-micrometer level, the metal layer may alternatively be structured by deposition of a suitable mask and etching to a width wider than the channel length. The gate sections positioned above the closely-adjacent electrodes are separated by the photo lacquer remaining under them to the point that the parasitic gate capacitances remain small as for field oxide (Diagram E-4-d' in Figure 4).

Another method to produce electronic components with closely adjacent electrodes on a substrate is shown in Figures 2 and 5 for the example of the production of a field-effect transistor. The structuring of these closely adjacent electrodes is performed as in the above-described method (Method 2). Holes or grooves for one or more gates buried are etched into those positions of the substrate at which no metal layer is present. In the subsequent method step, a second vapor-metal layer is deposited to the entire surface. Thin gate metallizations are deposited in the holes or grooves. An insulator is subsequently deposited on the surface thus produced. The holes or grooves are partially filled by the insulator. The insulation is etched away on the upper side of the substrate using, for example, a plasma process, and is only partially etched away in the holes or grooves because of the aspect ratios. The organic semiconductor ('active layer') is subsequently applied. After the surface of the substrate is sealed, the contacts of the buried gates must be exposed by means of a photolithographic process.

The methods based on the invention allow the production of electronic components with closely adjacent electrodes whereby the structuring of the electrodes is achieved by means of a single-mask process. Classical micro-structuring techniques may be used for this. Use of these methods allows simple, low-cost production of electronic components. The electronic components produced by the methods based on the invention may be reproduced better and more simply.

These methods may be applied advantageously in molecular electronics, to produce polymer field-effect transistors, field emitters, or other electronic components.